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IS 3136 (1965): Polycrystalline semiconductor rectifier equipment [ETD 31: Power Electronics]



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“Knowledge is such a treasure which cannot be stolen”

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Indian Standard
SPECIFICATION FOR
POLYCRYSTALLINE SEMICONDUCTOR
RECTIFIER EQUIPMENT
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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG

NEW DELHI 110002

Indian Standard

SPECIFICATION FOR POLYCRYSTALLINE SEMICONDUCTOR RECTIFIER EQUIPMENT

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Indian Standard

SPECIFICATION FOR POLYCRYSTALLINE SEMICONDUCTOR RECTIFIER EQUIPMENT

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 12 April 1965, after the draft finalized by the Power Converters Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard has been prepared with the object of laying down the performance requirements and testing procedures for the complete rectifier equipment making use of the polycrystalline semiconductor stacks. These stacks have been covered by IS : 2511-1963*.

0.3 In the preparation of this standard, assistance has been derived from the Pub 119-1960 'Polycrystalline semiconductor rectifier stacks and equipment' issued by the International Electrotechnical Commission. The weighting curves of EEI-BTS given in Appendix A have been reproduced from Vol. 79, Part I of the 1960 'Transactions' of the American Institute of Electrical Engineers (present Institute of Electrical and Electronic Engineers) with their kind permission.

0.4 This standard contains clauses which call for agreement between the purchaser and the supplier or which permit the purchaser to use his option for selection to suit his requirements. The relevant clauses are listed below:

6.2.2, 6.2.3, 6.2.4, 6.6.1, 7.1, 7.3.1.1, 7.5.2, 8.1, 9.1.1, 10.4, and B-1.12.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1060†. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard lays down the requirements and the tests applicable to the rectifier equipment using polycrystalline semiconductor rectifier stacks and used for supplying dc power from ac sources at frequencies up to 2 000 c/s.

NOTE — In the rectifier equipment covered by this standard, the impedance of ac system is assumed to have no influence on the operation of the rectifier equipment.

*Specification for polycrystalline semiconductor rectifier stacks.

†Rules for rounding off numerical values (*revised*).

1.2 This standard does not apply to the telecommunication rectifier equipment other than those for power supplied to such apparatus.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply in addition to the terms already defined in IS : 2511-1963*.

2.1 Total rms Ripple Voltage U_{σ} (on dc Side)

$$U_{\sigma} = \sqrt{\sum (U_n)^2}$$

where

U_n = rms value of harmonic of order n in dc voltage.

2.2 rms Ripple Voltage Ratio $\frac{U_{\sigma}}{U_{d1}}$

$$\frac{U_{\sigma}}{U_{d1}} = \frac{\sqrt{\sum (U_n)^2}}{U_{d1}}$$

where

U_n = rms value of harmonic of order n in dc voltage, and

U_{d1} = rated dc voltage of rectifier equipment.

2.3 Psophometric Ripple Voltage U_{ps}

$$U_{ps} = \frac{1}{p'_{800}} \times \sqrt{\sum (p'_f \times U_f)^2}$$

where

p'_{800} = weight given to frequency of 800 c/s in the weighting tables of CCITT† given in Appendix A,

p'_f = weight given to the frequency f in the weighting tables of CCITT† given in Appendix A, and

U_f = rms value of harmonic of frequency f in dc voltage.

NOTE — The psophometric ripple voltage is a characteristic for noise obtained in a telecommunication equipment fed from the rectifier equipment in question.

2.4 Psophometric Ripple Voltage Ratio — The ratio $\frac{U_{ps}}{U_{d1}}$

where

U_{ps} = psophometric ripple voltage (2.3), and

U_{d1} = rated dc voltage of rectifier equipment.

NOTE — The psophometric ripple voltage ratio is a characteristic for the noise obtained in a telecommunication equipment fed from the rectifier equipment in question.

*Specification for polycrystalline semiconductor rectifier stacks.

†International Telegraph and Telephone Consultative Committee.

2.5 Telephone Form Factor K' of CCITT*

$$K' = \frac{1}{U_{d1}} \times \frac{1}{p'_{800}} \times \sqrt{\sum (k_f p'_f U_f)^2}$$

where

U_{d1} = rated dc voltage of rectifier equipment;

p'_{800} = weight given to frequency of 800 c/s in the weighting table of CCITT* given in Appendix A;

k_f = factor of CCITT* which is a function of the frequency, considering the coupling between the power circuit and the light current line, and the service conditions of the power circuit. By convention $k_{800} = 1$;

p'_f = weight given to frequency f in the weighting table of CCITT* given in Appendix A; and

U_f = rms values of harmonic of frequency of f in dc voltage.

NOTE — Telephone form factor is a characteristic for the noise obtained in a light current line in the neighbourhood of the rectifier equipment in question, or from the lines connected to the rectifier equipment.

2.6 Telephone Influence Factor (TIF) of EEL-BTS†

$$\text{TIF} = \frac{1}{U_{d1}} \times \sqrt{\sum (p''_f \times U_f)^2}$$

where

U_{d1} = rated dc voltage of rectifier equipment;

p''_f = weight given to frequency f in the weighting curve of EEL-BTS† given in Appendix A; and

U_f = rms value of harmonic of frequency f in dc voltage.

NOTE — Telephone influence factor is a characteristic for the noise obtained in a light current line in the neighbourhood of the rectifier equipment in question, or from the lines connected to the rectifier equipment.

2.7 Load Filter Impedance — The impedance measured between the points on the positive and negative sides where the conductors from the rectifier equipment, from the battery and from the load are connected together, the rectifier equipment being disconnected on the dc side (see Fig. 1).

NOTE — When the load is parallel connected with a storage battery, a dc machine or a capacitor, or includes such a device, the ac impedance between the terminals will be very low. This low ac impedance, that is, the *load filter impedance*, is often utilized for smoothing the dc voltage. The load filter impedance is normally dependent on frequency; and in case of a storage battery in parallel with the load, it consists mainly of the resistance and the inductance of the battery cells and conductors, thus being dependent on the lay-out of the plant.

*International Telegraph and Telephone Consultative Committee.

†Joint Subcommittee on Research and Development, Edison Electric Institute and Bell Telephone System.

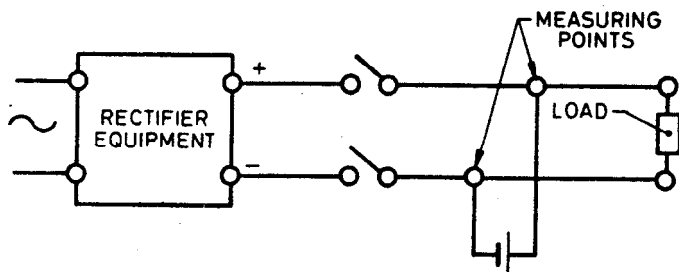


FIG. 1 LOAD FILTER IMPEDANCE

2.8 Power Efficiency — The ratio between the output on the dc side (as measured by a wattmeter) and the input active power on the ac side.

NOTE — In the conversion efficiency (see 2.28 of IS : 2511-1963*), the power of the ac components on the dc side is regarded as a power loss. In the power efficiency, it is regarded as a useful power. Therefore, the conversion efficiency has a lower value.

2.9 Natural Air Cooling — Cooling by the natural convection of the ambient air.

2.10 Cooling by Forced Ventilation — Cooling by a forced ventilation arrangement, for example, a fan. The air may be taken from the immediate proximity or from a place at a different temperature from that of the ambient air.

2.11 Tap Water Cooling — Cooling by water from an external supply.

2.12 Fluid to Air-Cooling — Cooling by a circulating heat transfer agent (gas or liquid), which is cooled by air. The fluid circulation and the air cooling may be natural or forced respectively.

2.13 Fluid to Water Cooling — Cooling by a circulating heat transfer agent (gas or liquid), which is cooled by water from an external supply, either in a heat exchanger or in a cooling duct within the fluid. The fluid circulation may be natural or forced.

2.14 Duty Factor — The type of duty of a rectifier equipment when not continuous as given in 2.14.1 and 2.14.2.

2.14.1 Intermittance Duty Factor — For intermittent load, where each load period is too short to give stationary temperature, it is the ratio between load time and total time between the beginnings of two sequential load periods.

NOTE — The intermittance factor influences the heating of the rectifier stack.

*Specification for polycrystalline semiconductor rectifier stacks.

2.14.2 Utilization Duty Factor — For non-continuous service, where each utilization period is long enough to give practically stationary temperature conditions, it is the ratio between utilization time and total time.

NOTE — The utilization factor indicates how extensively the device is used, thus influencing the service time.

2.14.3 The load may be steady or intermittent during the utilization periods. When the load is intermittent, it is also characterised by its intermittance duty factor.

2.15 Total Power Factor — The ratio of active power to apparent power.

2.16 Power Factor of the Fundamental Wave (Displacement Factor) ($\cos \phi$) — The ratio of active power of the fundamental wave to apparent power of the fundamental wave.

2.17 Distortion Factor — The ratio of total power factor to displacement factor.

2.18 Voltage Regulation — Unless otherwise specified, the difference between the dc voltage at open circuit and at rated direct current at specified character of load. If this includes the effect of automatic voltage regulation or other compensating means, it should be so stated.

2.19 Inherent Voltage Regulation — The voltage regulation given in 2.18 excluding the effect of ac system impedance.

2.20 Total Voltage Regulation — The voltage regulation including the effect of ac system impedance.

2.21 Corrected Voltage Regulation — The voltage regulation including the effect of an automatic voltage regulator, if used, over the load range.

2.22 Rated Frequency — The frequency at which the rectifier equipment is designed to operate.

2.23 Ambient Temperature for Rectifier Equipment — The temperature of the ambient air immediately surrounding the rectifier equipment.

2.24 Type Tests — Tests carried out to conformity with the standard. These tests are intended to prove the general qualities and design of a given type of a semiconductor rectifier equipment.

2.25 Routine Tests — Tests carried out on each semiconductor rectifier equipment to check requirements which are likely to vary during production.

3. INPUT VOLTAGE

3.1 Waveform

3.1.1 The input alternating voltage shall be sinusoidal at the ac terminals of the rectifier equipment, when the equipment is disconnected.

3.1.2 The waveform of the input voltage shall be considered sinusoidal if the largest deviation $(a - b)$ in Fig. 2, from the simultaneous value b of the fundamental wave, does not exceed 5 percent of the peak value c of the fundamental wave, that is

$$(a - b) \leq 0.05 c$$

For 12-phase rectifier without automatic asymmetry correction, this limit shall be reduced to 2.5 percent, that is

$$(a - b) \leq 0.025 c$$

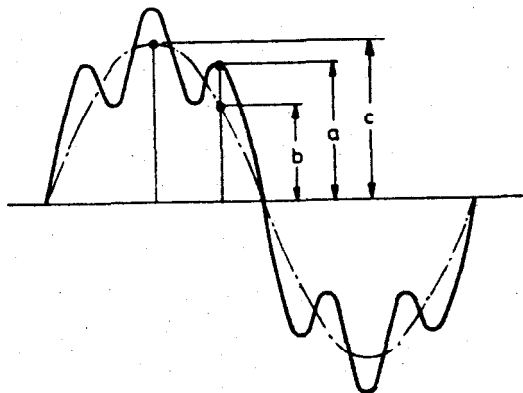


FIG. 2 WAVEFORM OF ALTERNATING VOLTAGE

3.2 Symmetry (For Polyphase Systems)

3.2.1 In the case of polyphase systems the input voltage shall be symmetrical.

3.2.2 The voltage shall be considered symmetrical, if neither the negative sequence nor the zero sequence component exceeds 5 percent of the positive sequence component.

3.2.3 If a polyphase system is not perfectly symmetrical but is within the limits of 3.2.2, the arithmetic mean value of all phase-to-phase voltages shall be taken as the line voltage.

4. OUTPUT VOLTAGE AND CURRENT CONTROL

4.1 The output voltage of a rectifier equipment may be controlled in different ways in order to eliminate the influence of variations in the input supply and to give it a dc output voltage-current characteristic suitable for its application. With regard to the fundamental design principles and their influence on the performance, the following kinds of rectifier equipment are distinguished.

4.1.1 Fixed Voltage (or Current) Rectifier Equipment — The equipment, where it is not possible to influence the dc voltage (or direct current) without interfering with its internal construction (Fig. 3).

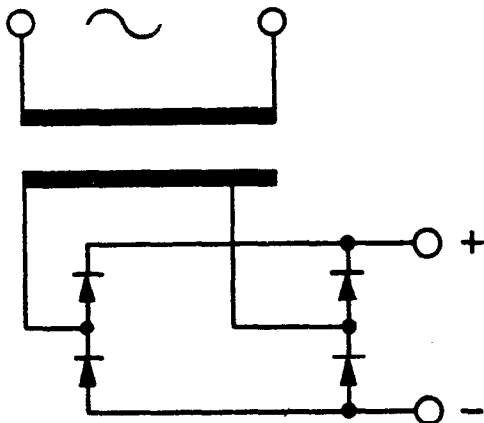


FIG. 3 FIXED VOLTAGE (OR CURRENT) RECTIFIER EQUIPMENT

4.1.2 Adjustable Voltage (or Current) Rectifier Equipment — The equipment, where it is possible to influence the dc voltage (or direct current) by adjustment devices, for example, a variable auto-transformer accessible to an operator (Fig. 4).

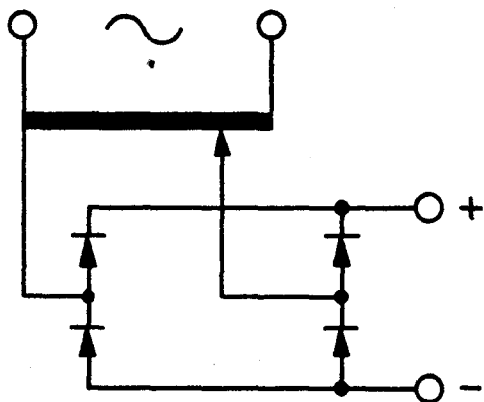


FIG. 4 ADJUSTABLE VOLTAGE (OR CURRENT) RECTIFIER EQUIPMENT

4.1.3 Inherent Characteristic Rectifier Equipment — The equipment which is equipped with devices (for example, reactors in ac circuit) which influence the dc voltage in order to obtain a determined output voltage-current characteristic not independent of alternating voltage (Fig. 5).

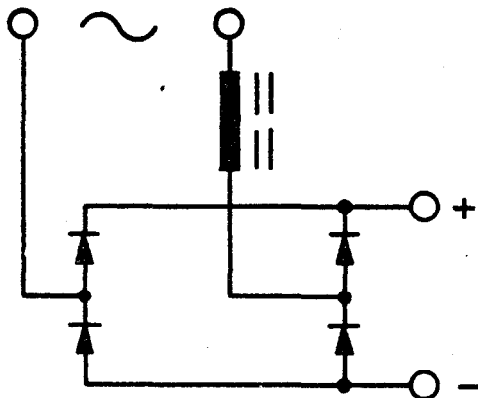


FIG. 5 INHERENT CHARACTERISTIC RECTIFIER EQUIPMENT

4.1.4 Stabilized Rectifier Equipment — The equipment which is provided with devices which influence the dc voltage (or direct current) in order to obtain a determined pattern of dc voltage-current characteristic independent of alternating voltage, where the devices are not influenced by the deviation of the dc voltage from its desired value (non-closed loop control) (Fig. 6).

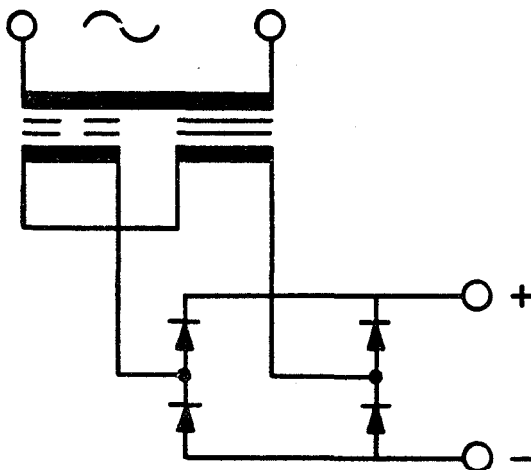


FIG. 6 STABILIZED RECTIFIER EQUIPMENT

4.1.5 Feed-Back Regulated Rectifier Equipment — The equipment which is provided with devices which automatically regulate the dc voltage (or direct current) in order to obtain a determined pattern of the dc voltage-current characteristic independent of the alternating voltage, where the devices are

influenced by the deviation of the dc voltage (or direct current) from its desired value (closed loop control) (Fig. 7).

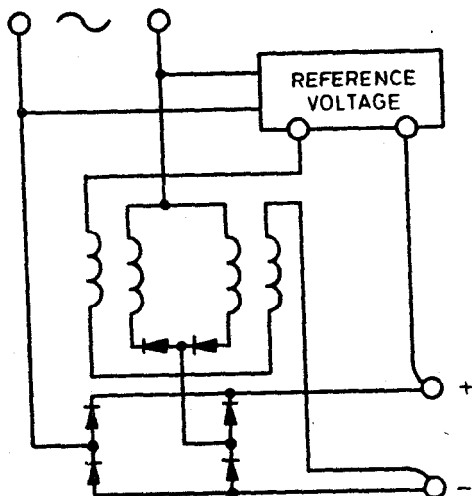


FIG. 7 FEED-BACK REGULATED RECTIFIER EQUIPMENT

5. STACKS AND TRANSFORMERS

5.1 Stacks — The polycrystalline semiconductor rectifier stacks used in the equipment shall conform to IS : 2511-1963*.

5.2 Transformers — The transformers conforming to IS : 2026-1962† shall be used in the rectifier equipment as far as they are not in contradiction with this standard.

6. RATINGS

6.1 All ratings shall be based on the principal tap/taps (that is, the specified tap/taps to be used at rated service of a new rectifier equipment).

6.2 Rated Service Conditions — The rated service conditions shall be those given in 6.2.1 to 6.2.4.

6.2.1 Load — The type of load shall be given.

6.2.2 Duty (*For Example, Duty Factor or Special Use*) — It shall be given in one of the following ways:

- a) Continuous duty;

*Specification for polycrystalline semiconductor rectifier stacks.

†Specification for power transformers.

- b) Intermittance duty factor;
- c) Utilization duty factor;
- d) The load time when the equipment is rated for short-time load; and
- e) Description of the service of equipment, for example, contactor supply or method of battery charging.

6.2.3 Ambient Temperature — The ratings of the rectifier equipment shall apply for an ambient temperature of 40°C.

NOTE — Other ambient temperatures of 45°C, 55°C and 70°C are also recognized and the manufacturer shall, on the request of the purchaser, provide a rating for the required temperature(s).

6.2.3.1 Where the ratings are dependent on the cooling medium temperature, the temperature of the same shall be stated.

6.2.4 Unusual Service and Installation Conditions — Conditions given in Appendix B shall be regarded as unusual and, if existing, shall be subject to agreement between the purchaser and the manufacturer.

6.3 Rated Direct Current — Rated direct current shall be given as the arithmetic mean value of the current at the dc terminals.

6.3.1 The preferred ratings in amperes shall be:

0.1, 0.16, 0.25, 0.4, 0.63, 1.0, 1.25, 1.6, 2.0, 2.5, 3.15, 4.0, 5.0, 6.3, 8.0, 10, 12.5, 16, 20, 25, 31.5, 40, 50, 63, 80, 100, 160, 250, 400, 630, 1 000, 1 600, 2 500, 4 000 and 6 300.

6.4 Rated dc Voltage — Rated dc voltage shall be given as the arithmetic mean value of the voltage between the dc terminals at rated service.

6.4.1 A rectifier equipment with substantially constant voltage, for parallel operation with a battery, may be equipped with means for increasing voltage for rapid charging of the battery. The rated dc voltage of such an equipment is given as the highest value of dc voltage to which the equipment may be set without the guaranteed corrected voltage regulation being exceeded. In addition to the rated dc voltage, information may be given on the possibilities of increasing the dc voltage for rapid charging.

6.4.2 A rectifier equipment for rapid charging of a battery may give a current which decreases at the end of the charging process, when the emf of the battery increases. The rated dc voltage of such an equipment is the highest dc voltage which may be obtained at rated direct current, which occurs at the beginning of the charging process. In addition to these ratings, information may be given on the highest dc voltage, which may be obtained at the end of the charging process, and the corresponding direct current (Fig. 8).

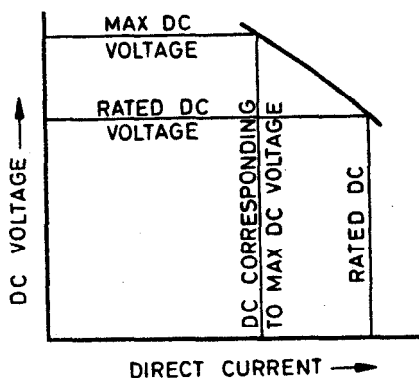


FIG. 8 RATED dc VOLTAGE

6.5 Rated ac Voltage — Rated ac voltage shall be given as the rms value of the sinusoidal phase-to-phase alternating voltage (*see also 3*) at rated service.

6.6 Rated Alternating Current — Rated rms alternating current of a rectifier equipment shall be given as the rms value of the current at the ac terminals at rated service.

6.6.1 The current is not assumed to be sinusoidal, and for rectifier equipments with more than 20 kW output power, the calculated approximate values of the most important harmonic currents shall be given on request.

6.6.2 When the rectifier stacks are subject to ageing, the rated rms alternating current shall be the one calculated for the fully aged condition (at the end of the rated service time).

6.7 Rated Frequency — The frequency of supply for which the rectifier is designed shall be given.

7. PERFORMANCE REQUIREMENTS

7.1 Direct Current — When the direct current of a rectifier equipment is automatically limited, the direct current shall not reach such a value that the characteristics of any semiconductor cells are permanently influenced, or any other component is heated to a temperature higher than that permitted in 7.9 when a dc voltage is decreased to a specified minimum value either by decreasing the load resistance or the counter-voltage of rectifier equipment rated for such load, for a time long enough for practically stationary temperature conditions to be reached.

When no minimum value is specified, it shall be assumed to be 70 percent of the rated dc voltage for rectifier equipment rated for battery load, and short-circuit for other rectifier equipment.

7.2 Direct Voltage — A rectifier equipment rated for battery load shall continuously withstand its highest possible dc voltage applied to the dc terminals when the ac supply is interrupted.

7.3 Regulation

7.3.1 For stabilized or feed-back regulated rectifier equipment, the corrected voltage regulation shall take into account the specified variation in rms alternating voltage, supply frequency, ambient temperature and load in most unfavourable combination which may occur in practice.

7.3.1.1 Where these variations are not indicated, the limits shall be those given in the Indian Electricity Rules.

7.3.2 For rectifier equipment designed to give a constant voltage, the guarantee on corrected voltage regulation shall apply for a direct current of 10 to 100 percent, unless otherwise specified.

7.3.3 For rectifier equipment designed to give a substantially constant current, the guarantee on current variation shall apply for a voltage range of 70 to 100 percent of rated voltage for battery charging rectifier equipment and from 10 to 100 percent for other equipment, unless otherwise specified.

7.4 Alternating Voltage — A rectifier equipment shall withstand 110 percent of rated ac voltage continuously at direct currents between zero and rated direct current, without any component being damaged or heated to a higher temperature than is permitted by **7.9** and without permanent change of the characteristics of the rectifier stack(s).

This requirement shall be fulfilled with the rectifier equipment connected and adjusted for rated alternating voltage.

NOTE — The components shall be so chosen or derated that they withstand continuously the overvoltages according to this clause.

7.4.1 When it is not possible to connect a rectifier equipment (which has been out of service) directly to 110 percent of its rated dc voltage without semiconductor rectifier stacks suffering damage or permanent change in their characteristics, the manufacturer shall state what procedure is to be followed to bring the equipment into service again.

7.5 ac Component on dc Side

7.5.1 The maximum value of the quantities defined in **2.1** to **2.6**, shall be suitable for application for the type of load. In case the load is connected in parallel with a battery or a capacitor, the guarantees shall apply for the load filter impedance as specified by the purchaser.

NOTE — A rectifier equipment for supplying telecommunication apparatus, practically always has to be provided with a smoothing filter for decreasing the ac components in

the dc voltage from the rectifier, which would disturb the telecommunication circuit. In such plants, where rectifier equipment are operated together with storage batteries, the battery is used not only as an emergency power source but also, because of its low internal impedance, as a shunt element in the smoothing filter. To be able to calculate the filter elements of the rectifier, the manufacturer has to know the impedance of the filter element which is represented by the battery with its conductors and other load, with which the rectifier equipment shall operate. Therefore, the load filter impedance shall be specified by the purchaser.

7.5.2 If the circuits are so complicated that it is not possible to give the load filter impedance (for example, when series cells are used), details about the guarantee shall be agreed to between the purchaser and manufacturer.

NOTE — If a battery is not continuously connected in parallel with the load, there is, any how in an equipment for supplying telecommunication apparatus, normally a large shunt capacitance which mainly determines the load filter impedance.

7.6 Protection

7.6.1 A rectifier equipment rated for battery load shall be protected against overcurrent on the dc side by means of a device which is able to interrupt the direct current which will occur if the rectifier equipment is connected with reverse polarity to its load battery.

7.6.2 For rectifier equipment, where the ac voltage of the rectifier stacks increases when the dc circuit is interrupted, the manufacturer shall:

- a) either design the rectifier stacks to withstand the increased ac voltage, or
- b) provide the rectifier equipment with a protective device which prevents the ac voltage from increasing above the rated ac voltage of the stacks, or
- c) clearly state that the dc circuit shall not be interrupted.

7.7 Ageing

7.7.1 The rectifier equipment shall give (for example, with suitable transformer taps) its rated dc voltage at the rated direct current at the end of the service time of the rectifier stacks in spite of their increased voltage drop.

7.7.2 A rectifier equipment provided with an automatic voltage regulator, or other compensating means shall be so designed that the guaranteed value of the corrected voltage regulation is not exceeded until the end of service time of the rectifier stacks in spite of their increased voltage drop.

7.8 Insulation

7.8.1 The insulation of those parts of the semiconductor rectifier equipment which are connected to the ac terminals shall fulfil the requirements of the appropriate Indian Standards.

7.8.2 The insulation of those parts of the semiconductor rectifier equipment which are insulated from the ac side shall, unless otherwise specified, withstand for a period of one minute, an ac rms test voltage having the frequency of 40 to 60 c/s and determined by the following formula but with a minimum of 2 000 V:

$$2 \times \frac{U_p}{\sqrt{2}} + 1\,000 \text{ volts}$$

U_p is the peak value of the highest voltage (transient over-voltages excluded) which occurs within the equipment in rated service.

7.8.3 Where $U_p/\sqrt{2}$ is not higher than 90 V, the insulation may be tested at a lower voltage value than given in **7.8.2** when it is clearly stated by the manufacturer.

7.8.4 In rectifier equipment having a rated dc voltage above 1 000 V, and so used that no overvoltage occurs on the dc side, the insulation may be tested at a lower voltage value than given in **7.8.2** when it is clearly stated by the manufacturer.

7.8.5 Different insulated circuits may be insulated for different test voltages. If the rectifier equipment includes devices which normally fall within the scope of other Indian Standards requiring dielectric test voltages lower than those given in **7.8.2**, **7.8.3** and **7.8.4**, such devices shall be disconnected before the remainder of the equipment is subjected to the test. The disconnected devices shall be tested separately for dielectric strength in accordance with the appropriate Indian Standards.

7.9 Heating

7.9.1 The temperature of new stacks used in rectifier equipment measured in accordance with **10.6** shall not exceed the rated stack temperature assigned by the manufacturer.

7.9.2 The temperature of the other components of a rectifier equipment at rated service shall not exceed the values in the appropriate Indian Standards for those components.

8. TOLERANCES ON GUARANTEE

8.1 In the event of guarantee being given, the following tolerances, shall, unless otherwise agreed to between the purchaser and the supplier, apply:

Power losses	± 10 percent of guaranteed value for equipment above 2 kW dc power
Efficiency	Corresponding to the tolerances for power losses
Displacement factor	$\pm 0.2 (1 - \cos \phi)$ for equipment above 10 kW dc power

dc voltage U_{d1}	$U_{d1} \leq 10V$ tolerance + 10 percent
	$10V < U_{d1} \leq 30V$ tolerance + 5 percent
	$U_{d1} > 30V$ tolerance + 3 percent
Voltage regulation (not corrected and for new equipment)	$U_{d1} \leq 30V$ tolerance \pm 30 percent
	$U_{d1} > 30V$ tolerance \pm 20 percent

8.2 For other quantities, where no tolerances are given, the guaranteed values are either maximum or minimum values.

9. MARKING

9.1 Every semiconductor polycrystalline rectifier equipment shall bear, in clear and durable signs, the following information (see Fig. 9):

- Manufacturer's name or trade-mark;
- Kind of semiconductor used in stacks;
- Rated rms ac voltage;
- Rated rms alternating current;
- Number of phases;
- Rated frequency;
- Rated dc voltage;
- Rated direct current;
- Duty (in accordance with **6.2.2**);
- Type of load if not obvious by other indications;
- External cooling medium if not ambient air;
- Cooling medium temperature. Not mandatory if the cooling medium is the ambient air in accordance with **6.2.3**;
- Quantity of insulating and/or cooling liquid, if any; and
- Country of manufacture.

9.1.1 For small equipment the information given may be reduced in consultation with the purchaser.

9.1.2 The semiconductor rectifier equipment may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

**MANUFACTURER
SELENIUM RECTIFIER EQUIPMENT**

TYPE No.

AC <input type="text"/> V	DC <input type="text"/> V
<input type="text"/> A	<input type="text"/> A
<input type="text"/> ~ <input type="text"/> c/s	<input type="text"/> SERVICE
<input type="text"/> kg OIL	<input type="text"/> LOAD
WEIGHT <input type="text"/> kg	
<input type="text"/>	
MADE IN INDIA	

**MANUFACTURER
SELENIUM RECTIFIER EQUIPMENT
FOR TRICKLE CHARGING**

TYPE No.

AC <input type="text"/> V	DC <input type="text"/> V
<input type="text"/> A	<input type="text"/> A
<input type="text"/> ~ <input type="text"/> c/s	<input type="text"/> LEAD CELLS
	<input type="text"/> ALKALINE CELLS
CONTAINS <input type="text"/> kg OIL	
<input type="text"/>	
MADE IN INDIA	

**MANUFACTURER
SELENIUM RECTIFIER EQUIPMENT
FOR INSULATION TESTING**

TYPE No.

AC <input type="text"/> V	<input type="text"/> kV
<input type="text"/> ~ <input type="text"/> c/s	<input type="text"/> mA
<input type="text"/>	
MADE IN INDIA	

**MANUFACTURER
SELENIUM RECTIFIER EQUIPMENT**

TYPE No.

FOR CHARGING xx BATTERIES
TYPE yy AT A AMPERES
SUPPLY VOLTAGE 240V 50 c/s

MADE IN INDIA

FIG. 9 EXAMPLES OF MARKING

10. TESTS

10.1 General

10.1.1 Type Tests — The following shall constitute the type tests;

- a) dc voltage-current characteristics (**10.2**);
- b) Automatic voltage regulator operation (**10.3**);
- c) Conversion efficiency (**10.4**);
- d) ac components on dc side (**10.5**);
- e) Temperature rise (**10.6**);
- f) High voltage (**10.7**);
- g) Inspection (**10.8**);
- h) Auxiliary devices (**10.9**); and
- j) Alternating current measurement (**10.10**).

10.1.2 Routine Tests — The following shall be carried out as routine tests:

- a) dc voltage-current characteristics (**10.2**),
- b) High voltage (**10.7**),
- c) Inspection (**10.8**),
- d) Auxiliary devices (**10.9**), and
- e) Alternating current measurement (**10.10**).

10.1.3 Tests on rectifier equipment shall normally be carried out at rated service conditions. Where this is impossible or practically unsuitable, the test may be carried out under other conditions which shall be stated.

10.2 dc Voltage-Current Characteristic — The dc voltage-current characteristics shall be plotted for rated character of the load or a circuit which is shown to give the same characteristics.

10.2.1 When conducted as routine test such points on dc voltage-current characteristic shall be checked which show that the guarantees on voltage regulation are fulfilled.

10.3 Automatic Voltage Regulator Operation — The operation of the automatic voltage regulator or other compensating means shall be checked by varying each one of the quantities, the influence of which shall be eliminated, while the others are kept constant.

10.3.1 This is preferably done by plotting one dc voltage-current characteristic for each of the maximum, normal and minimum value of the variable quantities.

10.4 Conversion Efficiency — The efficiency shall be given at the beginning as well as at the end of the service time. When the main transformer has several taps for different ac voltages, the efficiency shall be measured both for the principal tap (*see* 6.1) of the main transformer giving the highest and the one giving the lowest efficiency value.

The measurement of efficiency shall be carried out by either of the methods given in 10.4.1 and 10.4.2. The particular method chosen for the measurement shall be agreed to between the purchaser and the supplier.

10.4.1 The efficiency shall be measured when the rectifier equipment is fully loaded with the type of the load for which the ratings apply.

The arithmetic mean values of dc voltage and direct current shall be measured with moving coil instruments. The active input power on the ac side shall be measured with wattmeters of a type in which the harmonic currents cause negligible errors.

The efficiency shall be calculated according to the following formula:

$$\eta = \frac{(\text{dc voltage}) \times (\text{Direct current})}{(\text{Active input power})} \times 100 \text{ percent}$$

10.4.2 The efficiency shall be calculated from the measured values of the loss components.

As the wave-shapes of the current and voltages will not be the same in such a measurement as in rated service, loss values shall be recalculated to apply to the rated service. The method of these calculations shall be stated in the test report.

The following loss terms shall be included for giving efficiency:

- a) Power losses of the main rectifier stack or assembly, main transformer(s) and regulating devices, reactors, etc, in the main circuit;
- b) Power losses in wave filter or series smoothing reactor, if any;
- c) Power absorbed by auxiliary circuits, for example, voltmeter circuit or control circuits, which are continuously connected;
- d) Power absorbed by auxiliary devices (for example, pump motors) which are continuously connected; and
- e) The power of the ac components on the dc side, if any.

The following loss terms shall not be included when giving efficiency:

- a) Losses due to auxiliary apparatus, which operates only intermittently. The power consumption of such apparatus shall be given separately, and
- b) Losses due to the main connection between transformer and rectifier assembly and other main connections, if any, circuit-breaker,

isolating switches, switches and controlgear, when these are erected separately.

The efficiency shall be calculated according to the following formula:

$$\eta = \frac{(\text{dc voltage}) \times (\text{Direct current})}{(\text{dc voltage}) \times (\text{Direct current}) + (\text{Sum of power Losses})} \times 100 \text{ percent}$$

10.5 ac Components on dc Side — The ripple voltage in accordance with the definitions in 2.1 to 2.6 may be measured with the rectifier equipment connected to the load impedance (including battery unless otherwise specified), with which it is to operate finally. Such measurements are called *measurements at real load*.

For rectifier equipment for operation in parallel with a battery, it may in many cases be difficult and expensive for the manufacturer to provide a battery having the real value of the load filter impedance. In such cases, and when the output impedance for the ripple currents from the rectifier is high (that is always the case when the filter in the rectifier equipment has inductive exit), the measurements may be carried out directly or indirectly with a synthetic load-circuit. *This is called synthetic measurement.*

The connection is shown in Fig. 10. The impedance of the load L shall be small compared to the impedance of the rectifier equipment at all important frequencies. The impedance of the shunt Z shall fulfil the same conditions.

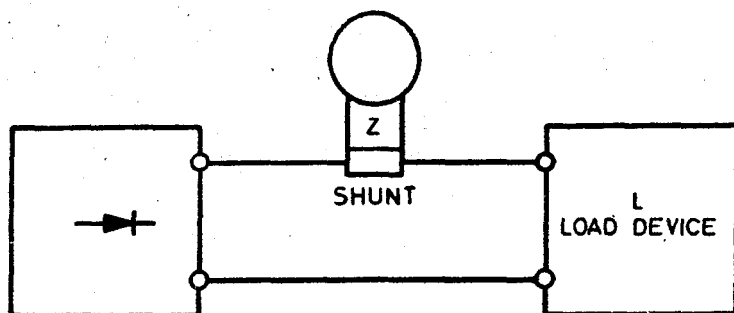


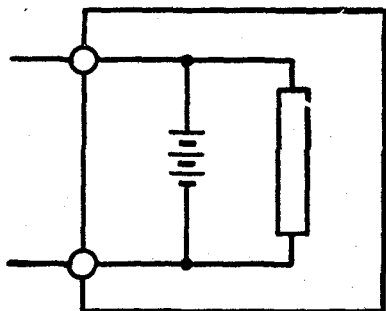
FIG. 10 SYNTHETIC LOAD MEASUREMENT

The load device L may be any arrangement fulfilling the requirement mentioned above, and able to consume dc power. When the device includes a machine, it shall be checked to confirm that no ac component from the machine (for instance, from the commutator or from the eccentricity of the rotor) disturbs the measurements. This is fulfilled when both the following conditions are met:

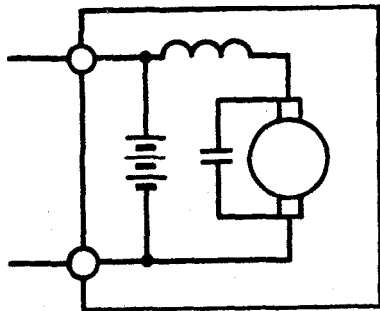
- a) No voltage component across the shunt Z from the machine alone shall be higher than 10 percent of the highest voltage component across Z from the rectifier equipment.

- b) The psophometric ripple voltage (see 2.3) across Z from the machine alone shall not be higher than 10 percent of the psophometric ripple voltage across Z from the rectifier equipment.

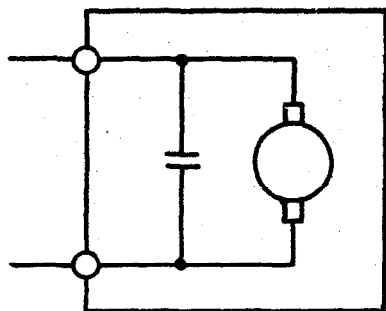
Figure 11 shows examples of load devices L , which will fulfil these requirements when properly designed.



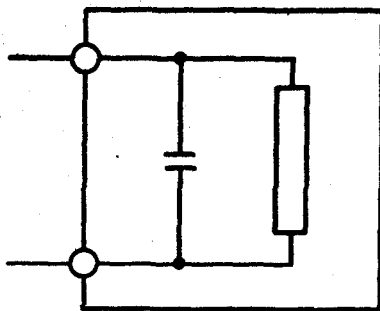
11A Battery or Counter-emf Cells and Resistance



11B Battery or Counter-emf Cells and dc Machine with Filter for Machine Ripple



11C dc Machine with Large Capacitor to Short-Circuit the Machine Ripple and to Obtain Low Impedance



11D Resistive Load with Large Capacitor to Obtain Low Impedance

FIG. 11 LOAD DEVICES

Dependent on the shunt Z , two methods are recognised for making the synthetic measurements.

One method is characterized by the fact that the shunt Z has a low inductance. This method is called *synthetic ripple current measurement*. The other method is characterized by the fact that the shunt Z is frequency

dependent in the same way as the load filter impedance (see 2.7) specified by the purchaser. This method is called *synthetic ripple voltage measurement*.

NOTE — The connections between the instrument and the test object shall be made in such a way, that no voltage is induced from magnetic fields, for example, with twisted or coaxial leads.

10.5.1 Total rms Ripple Voltage

- a) *Measurement at real load* — The total rms ripple voltage shall be measured by an ac voltmeter sensitive to rms value in series with a blocking capacitor with a negligible impedance in relation to the instrument.

NOTE 1 — When an accuracy of ± 25 percent is sufficient, a rectifier instrument, an oscillograph, or a vacuum tube voltmeter with no dc consumption, in series with a blocking capacitor, may be used.

NOTE 2 — It is also possible to measure the voltage of the various frequencies with a frequency selective instrument and calculate the total rms value in accordance with the definition given in 2.1.

- b) *Synthetic ripple current measurement* — The ripple current at different frequencies is measured as its voltage drop across the practically resistive shunt Z by means of a frequency selective instrument (for example, a wave analyzer). The corresponding ripple voltages are calculated by means of the specified values of the load filter impedance at different frequencies and the total rms ripple voltage is calculated according to 2.1.
- c) *Synthetic ripple voltage measurement* — The rms value of the ripple voltage across the shunt Z is measured by means of an rms voltmeter, which in this case is frequency dependent in the same way as the load filter impedance. The real ripple voltage is obtained by multiplying the reading with a constant k , which is calculated as:

$$k = \frac{\text{Specified load filter impedance}}{\text{Shunt impedance}}$$

10.5.2 rms Ripple Voltage Ratio — This is calculated in accordance with the definition given in 2.2 from the total rms ripple voltage measured in 10.5.1.

10.5.3 Psophometric Ripple Voltage

- a) *Measurement at real load* — The ripple voltage is measured at different frequencies, by means of a frequency selective instrument (for example, a wave analyzer), and the psophometric ripple voltage is calculated in accordance with the formula given in 2.3.

The measurements may also be carried out by means of an instrument called *psophometer* which directly indicates the psophometric ripple voltage.

When an accuracy of ± 25 percent is sufficient and when one frequency is known to dominate the ripple voltage, it is sufficient to measure

the total rms ripple voltage. The psophometric value is then calculated from that value using the weighting factor of the dominant frequency.

- b) *Synthetic ripple current measurement* — The ripple current at different frequencies is measured by means of a frequency selective instrument as a voltage drop across the practically resistive shunt Z . The corresponding ripple voltages are calculated by means of the specified value of the load filter impedance at the different frequencies. The psophometric ripple voltage is then calculated in accordance with 2.3.
- c) *Synthetic ripple voltage measurement* — The ripple voltage across the shunt Z , which in this case is frequency dependent in the same way as the load filter impedance, is measured at different frequencies by means of a frequency selective instrument. The ripple voltage at different frequencies is obtained by multiplication by the constant k according to 10.5.1 (c). The psophometric ripple is then calculated in accordance with 2.3.

The measurement may also be carried out by means of a psophometer connected across the shunt Z . The psophometric ripple voltage is then obtained by multiplying the indicated value by the constant k given in 10.5.1 (c).

When an accuracy of ± 25 percent is sufficient and when one frequency is known to dominate the ripple voltage, it is sufficient to measure that total rms ripple voltage. The psophometric value is then calculated from that value using the weighting factor of the dominant frequency.

10.5.4 Psophometric Ripple Voltage Ratio — This is calculated in accordance with the definition given in 2.4 from the psophometric ripple measured in 10.5.3.

10.5.5 Telephone Form Factor K' of CCITT — The telephone form factor of CCITT may be measured by means of a frequency selective instrument analogous with the psophometric ripple voltage as given in 10.5.3 (a), 10.5.3 (b), and 10.5.3 (c).

10.5.6 Telephone Influence Factor TIF of the EEI-BTS — The factor may be measured by means of frequency selective instrument analogous with the psophometric ripple voltage as given in 10.5.3 (a), 10.5.3 (b), and 10.5.3 (c).

10.6 Temperature Rise — The temperature rise shall be carried out at such service conditions which give the same losses as rated service. By agreement between the purchaser and the supplier the heat test may be made at such conditions that only the power losses are consumed from the ac supply.

The temperature of semiconductor stacks are measured with a thermocouple at the hottest accessible points. The thermocouples shall be in good

thermal contact with the cells, and well insulated from the ambient air. The conductors shall be thin. The measuring arrangement shall not appreciably influence the cooling.

The winding, temperatures of transformers and similar components shall be calculated from measurements of the winding resistance when cold and hot.

The temperatures of other components shall be measured by thermocouples well insulated from the ambient air, and in good thermal contact with the object to be measured, or with other methods specified in the appropriate Indian Standards.

The temperature of the incoming ambient air and the incoming and outgoing medium shall be measured with thermometers. The temperatures thus measured shall satisfy 7.9.

10.7 High Voltage — The test voltage shall be applied according to 7.8 for a period of one minute (*see* IS : 2071-1962*).

10.7.1 There shall be no breakdown or other evident deterioration.

10.8 Inspection — The equipment shall be subjected to a general inspection for the quality of workmanship and finish.

10.9 Auxiliary Devices — The functions of auxiliary devices, such as contactors, relays and pumps, shall be checked.

10.10 Alternating Current Measurement — The alternating current at rated service and no load shall be measured and checked.

APPENDIX A

(*Clauses 0.3, 2.3, 2.5 and 2.6*)

WEIGHTING TABLE OF CCITT† AND WEIGHTING CURVE OF EEI-BTS

A-1. Weighting table of CCITT† is given in Table 1.

A-2. The weighting curve of EEI-BTS is given in Fig. 12.

*Methods of high voltage testing.

†International Telegraph and Telephone Consultative Committee.

TABLE 1 WEIGHTS OF THE PSOPHOMETER FOR COMMERCIAL TELEPHONE CIRCUITS

(Clause A-1.)

FREQUENCIES c/s	WEIGHTS			
	Numerical Values	Square of the Numerical Values	Value in Decibels	Value in Nepers
(1)	(2)	(3)	(4)	(5)
16.66	0.056	0.003 136	-85.0	-9.79
50	0.71	0.5 041	-63.0	-7.25
100	8.91	79.3 881	-41.0	-4.72
150	35.5	1 260.25	-29.0	-3.34
200	89.1	7 938.81	-21.0	-2.42
250	178	31 684	-15.0	-1.73
300	295	87 025	-10.6	-1.22
350	376	141 376	- 8.5	-0.98
400	484	234 256	- 6.3	-0.73
450	582	338 724	- 4.7	-0.54
500	661	436 921	- 3.6	-0.41
550	733	537 289	- 2.7	-0.31
600	794	630 436	- 2.0	-0.23
650	851	724 201	- 1.4	-0.16
700	902	813 604	- 0.9	-0.10
750	955	912 025	- 0.4	-0.046
800	1 000	1 000 000	0.0	0.000
850	1 035	1 071 225	+ 0.3	+0.034
900	1 072	1 149 184	+ 0.6	+0.069
950	1 109	1 229 881	+ 0.9	+0.103
1 000	1 122	1 258 884	+ 1.0	+0.115
1 050	1 109	1 229 881	+ 0.9	+0.103
1 100	1 072	1 149 184	+ 0.6	+0.069
1 150	1 035	1 071 225	+ 0.3	+0.034
1 200	1 000	1 000 000	0.0	0.000

(Continued)

**TABLE 1 WEIGHTS OF THE PSOPHOMETER FOR COMMERCIAL
TELEPHONE CIRCUITS — *Contd***

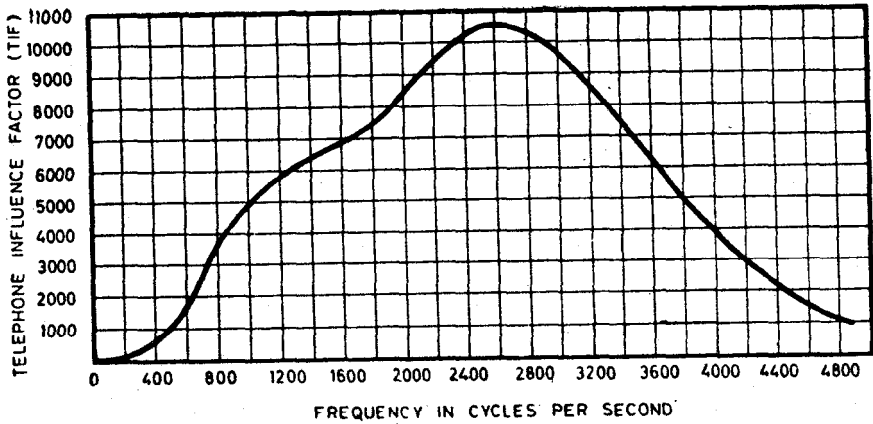
FREQUENCIES c/s	WEIGHTS			
	Numerical Values	Square of the Numerical Values	Value in Decibels	Value in Nepers
(1)	(2)	(3)	(4)	(5)
1 250	977	954 529	— 0.20	—0.023
1 300	955	912 025	— 0.40	—0.046
1 350	928	861 184	— 0.65	—0.075
1 400	905	819 025	— 0.87	—0.100
1 450	881	776 161	— 1.10	—0.126
1 500	861	741 321	— 1.30	—0.150
1 550	842	708 964	— 1.49	—0.172
1 600	824	678 976	— 1.68	—0.193
1 650	807	651 249	— 1.86	—0.214
1 700	791	625 681	— 2.04	—0.234
1 750	775	600 625	— 2.22	—0.255
1 800	760	577 600	— 2.39	—0.275
1 850	745	555 025	— 2.56	—0.295
1 900	732	535 824	— 2.71	—0.311
1 950	720	518 400	— 2.86	—0.329
2 000	708	501 264	— 3.00	—0.345
2 050	698	487 204	— 3.12	—0.359
2 100	689	474 721	— 3.24	—0.373
2 150	679	461 041	— 3.36	—0.386
2 200	670	448 900	— 3.48	—0.400
2 250	661	436 921	— 3.60	—0.414
2 300	652	425 104	— 3.72	—0.428
2 350	643	413 449	— 3.84	—0.442
2 400	634	401 956	— 3.96	—0.456
2 450	625	390 625	— 4.08	—0.470
2 500	617	380 689	— 4.20	—0.484
2 550	607	368 449	— 4.33	—0.499
2 600	598	357 604	— 4.46	—0.513
2 650	590	348 100	— 4.59	—0.528
2 700	580	336 400	— 4.73	—0.544
2 750	571	326 041	— 4.87	—0.560
2 800	562	315 844	— 5.01	—0.576

(Continued)

TABLE 1 WEIGHTS OF THE PSOPHOMETER FOR COMMERCIAL TELEPHONE CIRCUITS — *Contd*

FREQUENCIES c/s	WEIGHTS			
	Numerical Values	Square of the Numerical Values	Value in Decibels	Value in Nepers
(1)	(2)	(3)	(4)	(5)
2 850	553	305 809	— 5.15	—0.593
2 900	543	294 849	— 5.30	—0.610
2 950	534	285 156	— 5.45	—0.627
3 000	525	275 625	— 5.60	—0.645
3 100	501	251 001	— 6.00	—0.691
3 200	473	223 729	— 6.50	—0.748
3 300	444	197 136	— 7.05	—0.812
3 400	412	169 744	— 7.70	—0.886
3 500	376	141 376	— 8.5	—0.979
3 600	335	112 225	— 9.5	—1.09
3 700	292	85 264	—10.7	—1.23
3 800	251	63 001	—12.0	—1.38
3 900	214	45 796	—13.4	—1.54
4 000	178	31 684	—15.0	—1.73
4 100	144.5	20 880.25	—16.8	—1.93
4 200	116.0	13 456	—18.7	—2.15
4 300	92.3	8 519.29	—20.7	—2.38
4 400	72.4	5 241.76	—22.8	—2.62
4 500	56.2	3 158.44	—25.0	—2.88
4 600	43.7	1 909.69	—27.2	—3.13
4 700	33.9	1 149.21	—29.4	—3.38
4 800	26.3	691.69	—31.6	—3.64
4 900	20.4	416.16	—33.8	—3.89
5 000	15.9	252.81	—36.0	—4.14
> 5 000	< 15.9	< 252.81	< —36.0	< —4.14
*5 000 to 6 000	< 15.9	< 252.81	< —36.0	< —4.14
> *6 000	< 7.1	< 50.41	< —43.0	< —4.95

*If for certain telephone transmission systems calculations are to be made from the psophometric weights, and if it appears necessary to have for frequencies greater than 5 000 c/s values more precise than those given, these values may be adopted.



1960 SINGLE FREQUENCY TIF VALUES

FREQ	TIF	FREQ	TIF	FREQ	TIF	FREQ	TIF
60	0.5	1 020	5 100	1 860	7 820	3 000	9 670
180	30	1 080	5 400	1 980	8 330	3 180	8 740
300	225	1 140	5 630	2 100	8 830	3 300	8 090
360	400	1 260	6 050	2 160	9 080	3 540	6 730
420	650	1 380	6 370	2 220	9 330	3 660	6 130
540	1 320	1 440	6 650	2 340	9 840	3 900	4 400
660	2 260	1 500	6 680	2 460	10 340	4 020	3 700
720	2 760	1 620	6 970	2 580	10 600	4 260	2 750
780	3 360	1 740	7 320	2 820	10 210	4 380	2 190
900	4 350	1 800	7 570	2 940	9 820	5 000	840
1 000	5 000						

FIG. 12 WEIGHTING CURVE

APPENDIX B

(Clause 6.2.4)

UNUSUAL SERVICE AND INSTALLATION CONDITIONS

B-1. CONDITIONS

B-1.1 Unusual mechanical stresses, for example, shocks and vibrations.

B-1.2 Cooling water which may cause corrosion or obstruction, for example, sea-water or hard water.

B-1.3 Foreign particles in the ambient air, for example, abnormal dirt or dust.

B-1.4 Salt air (for example, proximity to the sea), high humidity, dripping water or noxious gases, for example, mercury vapour (particularly dangerous), chlorine, sulphurous vapours, etc.

B-1.5 Exposure to steam or oil vapour.

B-1.6 Exposure to explosive mixture of dust or gases.

B-1.7 Fluid containing radio-active particles.

B-1.8 Ambient temperature, if different from those specified in 6.2.3.

B-1.9 High values of relative humidity and temperature.

B-1.10 Considerable and rapid fluctuations of temperature and humidity.

B-1.11 Altitude of more than 1 000 m above sea level.

B-1.12 More than six months' storage time.

NOTE — When this storage time is to be exceeded, the purchaser and the manufacturer may agree on special packing and reforming process for the stacks of the equipment. It may be noted that in certain cases normal reforming may be necessary even if the storage time is less than six months.

B-1.13 Superposed high-frequency voltages.

B-1.14 Frequencies different from 50 c/s.

B-1.15 Unusual conditions not covered by **B-1.1** to **B-1.14** shall also be subject to special agreement between the purchaser and the manufacturer.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

QUANTITY	UNIT	SYMBOL
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

QUANTITY	UNIT	SYMBOL
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

QUANTITY	UNIT	SYMBOL	DEFINITION
Force	newton	N	1 N = 1 kg.m/s ²
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m ²
Frequency	hertz	Hz	1 Hz = 1 c/s
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m ²

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Eastern : 5 Chowringhee Approach

CALCUTTA 700072

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MADRAS 600113

Northern : B69, Phase VII

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(MOHALI) 160051

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5-8-56C L. N. Gupta Marg

HYDERABAD 500001

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